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Design, Construction and Experiment on Imbert Downdraft Gasifier Using South Sumatera Biomass and Low Rank Coal as Fuel

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ABSTRACT
The solid fuel must be converted to gas fuel or liquid fuel for application to internal combustion engine or gas turbine. Gasification is a technology to convert solid fuel into combustible gas. Gasification system generally consists of a gasifier, cyclone, spray tower and filter. This study is purposed to design, construction, and experiment of gasification system. The imbert downdraft gasifier was designed with 42 kg/h for the maximum capacity of fuel consumption, 90 cm for height, 26.8 cm for main diameter and 12 cm for throat diameter. The gasifier was constructed from stainless steel material of SUS 304. Biomass and low rank coal from South Sumatera, Indonesia was used as fuel. The result of the experiment showed that combustible gas was produced after 15 minutes operation in average. The air fuel ratio of low rank coal was 1.7 which was higher than biomass (1.1). Combustible gas stopped producing when the fuel went down below the throat of gasifier.
***Keywords*:** Design, Construction, Experiment, Imbert Downdraft Gasifier, Biomass, low rank coal

I. INTRODUCTION

Decreasing of crude oil as the energy resource will cause the need to finds the alternative of energy. The alternative of energy resource can be obtained from solid fuel. Direct utilization of solid fuel for internal combustion engine was not yet possible. The solid fuel must be converted into gas or liquid fuel. Gasification process is one of the technology that could converts solid fuel into gas fuel and has a compatible value to the crude oil [1]. Gasification process could be done on several types of gasifier. One of the most common types of gasifier is imbert downdraft as shown in Fig 1. This type of gasifier has the advantage at the low tar content in producer gas, so it can be used for internal combustion engine [2-3]. The low tar content is caused by pyrolysis gas before leaving the reactor that will be passed through the combustion zone and reduction zone (high temperature of char), so tar will be cracked into combustible gas [3-4]. Downdraft gasifier has special characteristics where the combustion zone at the center of reactor and has less diameter (throat) than the main reactor. This condition cause the gasification process more complicated. The gas production is influenced on the diameter of throat and the continuity of fuel flow down inside of the reactor especially when it passed through the throat [5-6]. Fuel continuity went down depending on the proportionality of fuel size to the throat diameter. The suitable design will help the production of combustible gas in gasification process. Some designs and experiment were done on the downdraft gasifier [7-12]. The design generally used different approach and various material constructions, therefore they would produce different characteristic of operation. Only few researchers explained the design, construction and experiment of gasification system (imbert downdraft gasifier, cyclone, spray tower, filter). This study aims to design, construction, and experiment of the imbert downdraft gasifier using South Sumatera, Indonesia biomass and low rank coal as fuel.

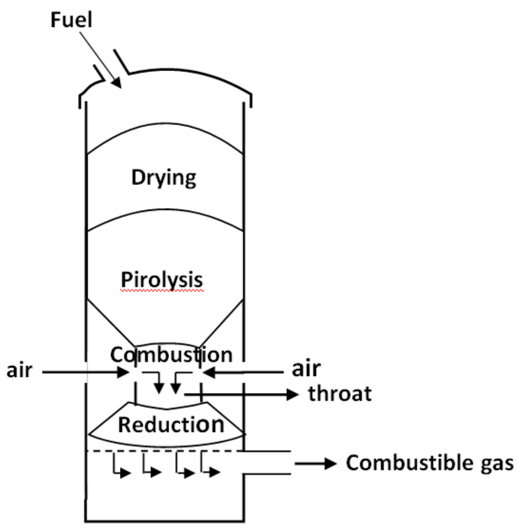

Figure 1. Imbert Downdraft Gasifier**.**

II. MATERIAL AND METHODS

The study was started on designing of each component of gasification system then it was continued with construction or manufacturing and finally has done experiment of gasification system.

Design of the imbert downdraft gasifier, cyclone and spray tower base on principle design was reported by Reed et.al [13]. Filter was designed following approach by Ramansamy et.al [14].

The construction material of the imbert downdraft gasifier was used stainless steel SUS 304 with a thickness of 3 mm [15]. Cyclone was constructed by mild steel with a thickness of 2 mm .Spray tower and filter was made by SUS 304 with a thickness of 2 mm. Gasifier was covered by ceramic fiber wool with 5 cm of thickness to ignore the heat lost to surroundings. The gasification air was supplied to the combustion zone using a suction blower with a maximum capacity of 350 lpm.

The experiment perbatch system was done using low rank coal (MT-46) and biomass (coconut sheel) from South Sumatera, Indonesia as fuel. The bulk density of fuel were 682 kg/m^3 for low rank coal and 397 kg/m^3 for biomass. Low rank coal and biomass had each of 2 cm x 2 cm x 1 cm in size and 2 cm x 2 cm x 2 mm in size as shown on Fig 2-3.

Figure 2. Biomass

Figure 3. Low rank Coal

The amount of air stoichiometric was calculated using equation (1),

$$\text{Stoikiometric of air} = \frac{1}{0{,}232}\left[\frac{8}{3}C + 8H_2 + S - O_2\right] \text{ (kg of air/kg of fuel)} \quad (1)$$

C, H_2, S and O_2 is mass fraction of each component in ultimate analysis from Table 1 and 2. The gasification air is 19% to 43% of air stoikiometric [16]. The amount of gasification air must be supplied into gasifier could be calculated using a assumption of the fuel consumption rate about 6 kg/h. The amount of gasificaton air from calculating was 6.4 to 14.4 kg/h for biomass and 8.6 to 19.4 kg/h for low rank coal. The actual air gasification and gas flow rate were measured using orifice flat flow meter.

Table 1. The Proximate and Ultimate of biomass

Proximate Analysis	Unit	Value
Moisture	Mass Fraction (%)	5.3
Ash	Mass Fraction (%)	6.26
Volatile	Mass Fraction (%)	70,7
Fixed Carbon	Mass Fraction (%)	17.54
Ultimate Analysis		
Carbon	Mass Fraction (%)	47.59
Hydrogen	Mass Fraction (%)	6.0
Oxygen	Mass Fraction (%)	45.52
Nitrogen	Mass Fraction (%)	0.22
Sulphur	Mass Fraction (%)	0.09
Heating Value		
Gross CV	kcal/kg (Adb)	5574

Table 2. The Proximate and Ultimate of Low Rank Coal

Proximate Analysis	Unit	Value
Moisture	Mass Fraction	27.79
Ash	Mass Fraction	5.13
Volatile	Mass Fraction	33,72
Fixed Carbon	Mass Fraction	33.37
Ultimate Analysis		
Carbon	Mass Fraction	57.35
Hydrogen	Mass Fraction	4.31
Oxygen	Mass Fraction	17.37
Nitrogen	Mass Fraction	0.77
Heating Value		
Gross CV	kcal/kg (adb)	5695

III. RESULT AND DISCUSSION

3.1. Design

3.1.1. Imbert Downdraft gasifier

According to Reed et.al [14] used fuel consumption rate therefore would get the main dimension of gasifier. The maximum of fuel consumption of 42 kg/h was used on design. The main dimensions of the reactor was obtained such as : diameter of gasifier (dr), diameter of throat (dh), high of the reactor from the bottom to the air inlet (R + H), high of the reactor from air inlet to the upper reactor (H'), air inlet tuyer diameter (dn) and number of air inlet tuyer (n). Five of air inlet tuyer were used to supply air gasification. All the dimension are explained in Table 3 and Fig 4.

Table 3. Dimension of Gasifier

No	Dimension	Value
1	H'	54.4
2	H	25.6
3	R	10
4	dr	26.8
5	dh	12
6	dn	1.2

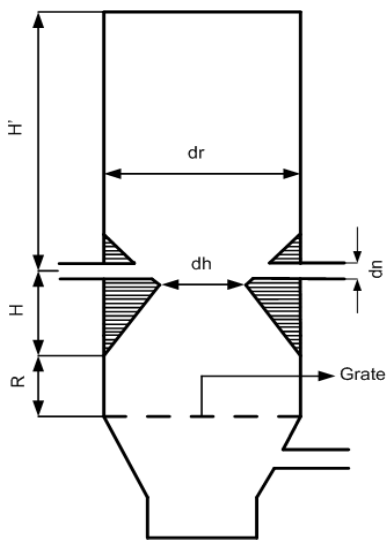

Figure 4. Imbert Downdraft Gasifier

3.1.2. Cyclone

The maximum of gas flow rate of 994 lpm with the gas velocity of 15 m/s and temperature of 300 ^oC were designed to pass through cyclone. The main dimension of geometry of the cyclone was obtained as shown in Table 4 and Fig 5.

Table 4. Dimension of Cyclone

No	Dimension	Value (cm)
1	Bc	3.75
2	Dc	15
3	Hc	7.5
4	Lc	30
5	Zc	30
6	Jc	3.75
7	Dp	7.5
8	Qc	10

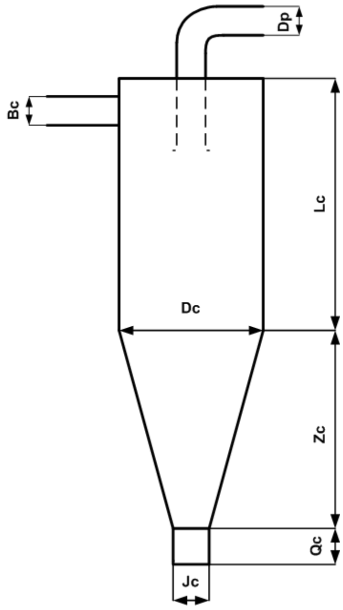

Figure 5. Cyclone

3.1.3. Spray tower

Spray tower was designed for the superficial gas velocity of 0.6 – 1.21 and gas flow rate of 994 lpm through the spray tower. The diameter of spray tower was obtained of 13-18 cm. In this design, the diameter of spray tower was used of 15 cm. The other dimension is displayed in Table 5 and Fig 6.

Table 5. Dimension of Spray Tower

No	Dimension	Value (cm)
1	H_1	30
2	H_2	15
3	H_3	15
4	D	15

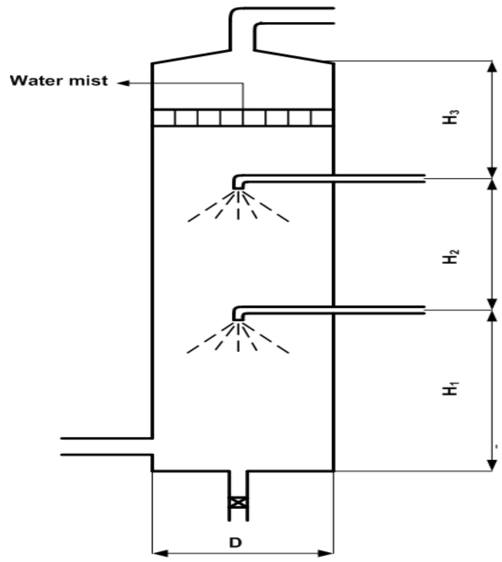

Figure 6. Spray Tower

3.1.4. Filter

Filter was designed base on the retention time gas in filter of 3.5 second. The filter high ($h_1+h_2+h_3+h_4$) was designed about 70 cm then the filter diameter (D_f) was obtained Dimension detail is shown in Table 6 and Fig 7. Filter was constructed with two stage. the first stage was used charcoal and the second stage was used cotton as filter.

Table 6. Dimension of Filter

No	Dimension	Value (cm)
1	h_1	15
2	h_2	20
3	h_3	20
4	h_4	15
5	D_f	32

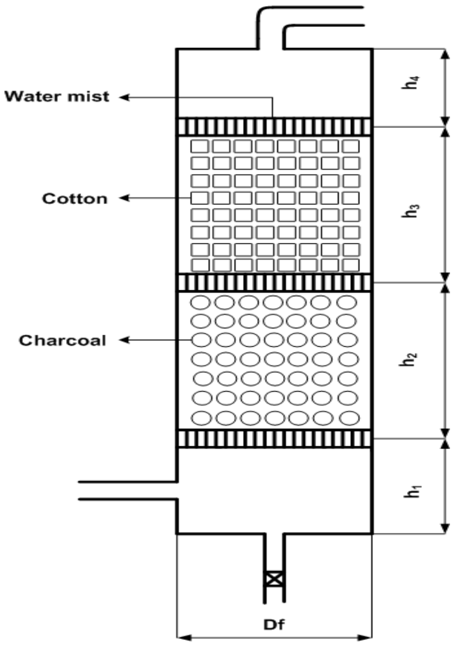

Figure 7. Filter

3.2. Construction

Gasification system was constructed as shown in Fig 8. The arrangement of gasification system was gasifier, cyclone, spray tower 1, spray tower 2, filter and gas burner,

The leakage of gas testing was done to see the leakage on gasification system. The testing showed free of leakage on all of gasification component including of piping system.

Figure 8. The Construction of Gasification System

3.3. Experiment

The result of experiment showed a indicating amount of fuel consumption was not the same with the predicting (6 kg/h) as shown in Table 7. It was caused by the reactivity of the fuel influenced by many variables such as size, shape, bulk density etc. The amount of actual gasification air confirmed to predicting gasification air as shown in Table 7.

The air fuel ratio of gasification had value of 1.14 to 1.7 was not difference with reported by Lun et.al and Doghru et.al [17-18]. Combustible gas was obtained after 15 minutes of start up, it is suitable with the result was reported by Seggiani et.al and Surjosatyo et.al [19-20]. The mass flow rate of gas was approximately of 80% of total of air and fuel mass flow rate that had same trend with the result Doghru et.al and Kumararaja et.al [18,21].

The flame was produced biomass more yellow than low rank coal but low rank coal more blue as shown in Fig 9-10, due to biomass had more volatile than low rank coal as shown in Table 1-2. The air fuel ratio of low rank coal more than biomass was caused by the higher moisture content of low rank coal. The combustible gas stoped producing when the fuel position inside of the gasifier passed through the throat zone.

Table 7. The Results of Experimental

No	Air Mass Flow Rate (kg/h)	Fuel Mass Flow Rate (kg/h)	Gas Mass Flow Rate (kg/h)	Air/Fuel Ratio	Duration of Time to get combustible gas
Biomass					
1	7,9	6.9	11.8	1.14	10
2	7,9	6,7	11.8	1.2	15
3	7,9	6,7	11.8	1.2	14
Average	7.9	6.8	11.8	1.16	13
Low rank coal					
1	8.5	5.2	11.8	1.6	15
2	8.5	4.9	11.8	1.7	15
3	8.5	5.0	11.8	1.7	16
Average	8.5	5.0	11.8	1.7	15

Figure 9. Biomass Flame

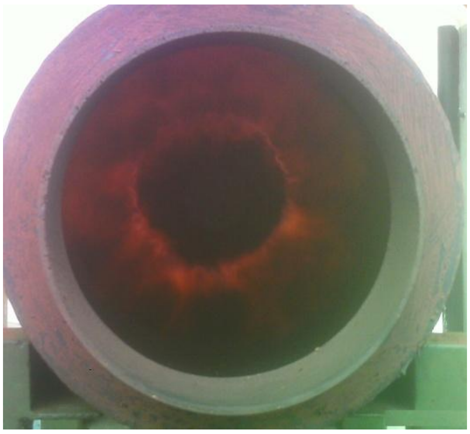

Figure 10. Low Rank Coal Flame

IV. CONCLUSION

Gasification system consists of gasifier, cyclone, spray tower and filter that has been designed, manufactured and experimented. The system could operate properly perbatch at integrated system (gasifier + cyclone + spray tower + filter). The gasification system operated properly using biomass and low rank coal as fuel. The air fuel ratio biomass and low rank coal respectively of 1.1 and 1.7. The combustible gas was produced after 15 minutes of start up. The combustible gas stopped producing when the fuel position inside the gasifier passed through the throat zone.

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